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DOI: https://doi.org/10.1093/ejcts/ezx308

Originally published at:
Wang, Changtian; Regar, Evelyn; Lachat, Mario; von Segesser, Ludwig K; Maisano, Francesco; Ferrari, Enrico (2018). Endovascular treatment of non-dissected ascending Aorta disease: a systematic review. European Journal of Cardio-Thoracic Surgery, 53(2):317-324.
DOI: https://doi.org/10.1093/ejcts/ezx308

European Journal of Cardio-Thoracic Surgery 0 (2017) 1–8
doi:10.1093/ejcts/ezx308

Cite this article as: Wang C, Regar E, Lachat M, von Segesser LK, Maisano F, Ferrari E. Endovascular treatment of non-dissected ascending aorta disease: a systematic review. Eur J Cardiothorac Surg 2017; doi:10.1093/ejcts/ezx308.

Endovascular treatment of non-dissected ascending aorta disease: a systematic review

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Received 23 May 2017; received in revised form 19 July 2017; accepted 30 July 2017

Summary

Severe ascending aorta disease includes aneurysms, pseudoaneurysms (ascending aorta pseudoaneurysms), penetrating aortic ulcers and Type A aortic dissections. Surgical replacement of the aortic root, ascending aorta or aortic arch is the common treatment for severe ascending aortic disease involving the root, the ascending aorta and/or the arch. Despite good surgical results, there is still a risk for morbidity and mortality following surgery for ascending aorta replacement when elderly patients or patients at high risk for surgery are concerned. Less invasive endovascular treatments for ascending aorta repair are under evaluation, and some reports appeared in the available literature in the last decade. However, clinical series or randomized studies are not yet available, and the use of these techniques is still questionable. In this study, we analysed the outcomes of reported cases of endovascular treatment for ascending aorta disease, excluding Type A aortic dissection. We reviewed reports published until February 2017, and we evaluated the employed technology, the devices, the procedural steps and the outcomes. A total of 26 articles reported 67 patients (mean age 65 ± 17 years) who received endovascular treatment for ascending aorta disease: aneurysms, ascending aorta pseudoaneurysms, penetrating aortic ulcers, intramural haematoma, thrombosis, iatrogenic coarctation and aortic rupture. Complications included endoleak (9 cases), stroke (3 cases), non-ST-elevation myocardial infarction (1 case) and splenic infarction (1 case). Three patients required conversion to open surgery, and 1 patient underwent endovascular reintervention. Early mortality was 2.9%. As an alternative treatment for ascending aorta disease in selected high-risk patients, the endovascular repair will gain popularity, but further analysis is required.

Keywords: Endovascular ascending aorta repair • Catheter-based techniques • Ascending aorta disease

INTRODUCTION

Ascending aorta disease includes several pathological findings, such as real aneurysms, pseudoaneurysms, dissections, mural haematoma, penetrating ulcers, and all are potential life-threatening diseases requiring prompt medical and surgical treatment. The surgical treatment represents the most valuable therapeutic option to prevent adverse events or to save lives when aortic ruptures or Type A aortic dissections occur. However, despite the low mortality rate and the good short- and long-term outcomes of standard surgical treatment, complications and mortality rate can still be higher as long as elderly patients, redo patients or patients affected by severe concomitant diseases are concerned: in a recent report of 1221 elective proximal aorta replacements, the overall early mortality rate was 4.2% (including isolated ascending aorta, concomitant root and concomitant arch replacement), and it raised up to 7.9% in patients aged 70 years or older [1]. The higher age, the chronic renal insufficiency and previous cardiac surgery were independent predictors for increased early mortality.

As an alternative treatment, catheter-based techniques draw more and more attention, and, recently, they have been employed in isolated cases or in short case series for the treatment of non-dissected ascending aorta diseases. In the last decade, published reports have demonstrated that the use of catheter-based techniques for ascending aorta disease represent a potential life-saving therapeutic option that provides a period of time for stable clinical condition allowing for planning of more definitive treatments [2]. More recently, the successful use of catheter-based techniques has been reported in Type A aortic dissection treatments and other serious ascending aorta diseases [3]. The endovascular repair of Type A aortic dissections was previously reviewed in an earlier publication [4]. In this review, we examined the current status of catheter-based techniques in treating ascending aorta disease (ascending aorta aneurysm, pseudoaneurysm, penetrating ulcer, thrombosis and rupture), excluding acute and chronic ascending aorta dissections.

METHODS

We searched in MEDLINE with time point set to the end of February 2017 using medical subject headings and text words supplemented by scanning the bibliographies of retrieved articles. We combined 'endovascular treatment' and 'ascending aorta' using the Boolean operator 'AND'. We used similar search strategies using the terms 'endovascular repair', 'endovascular stent grafting', 'endograft repair', 'endovascular stent grafts', 'transcardiac endograft delivery' and 'proximal ascending aorta'. Language was limited to articles written in English. Two coauthors (C.W. and L.K.v.S.) reviewed and selected relevant articles for inclusion. Differences were resolved in consensus discussions.

Inclusion criteria

We used 'endovascular treatment of the ascending aorta diseases' as the initial retrieval. All cases received endovascular stent grafts for the ascending aorta. Only articles published in English that reported overall morbidity and mortality data, definitive treatment modalities used and configuration of catheter-based techniques were included.

Exclusion criteria

All articles or cases reporting on the treatment of ascending aorta dissection were excluded. Correspondences, expert opinion and review were also not included.

Data extraction

We collected data on method design (retrospective or case report), aortic disease, age, gender, case numbers, stent graft type, access route, follow-up, complications, mortality, cause of death and reinterventions.

Statistical analysis

Data collected were organized on an Apple Numbers (version 6.6.2) spreadsheet. Descriptive statistics were used to describe the demographics and continuous data (e.g. mean ± standard deviation). Dichotomous variables were expressed as numbers with percentages.

RESULTS

The search intended for 'endovascular treatment of the ascending aorta' [ti], 'endovascular treatment' [ti] AND 'ascending aorta' [ti] showed no results. Then, we expanded the scope of retrieval with different combinations: endovascular treatment of the ascending aorta, endovascular treatment, endovascular repair or endovascular stent grafting or endograft repair or endovascular stent grafts or transcardiac endograft delivery AND ascending aorta. From the initial search, 5660 articles were found. We screened them by the title/abstract and full text. Finally, 26 articles were selected and reviewed, spanning a period of time ranging from 2007 to 2016 (Fig. 1).

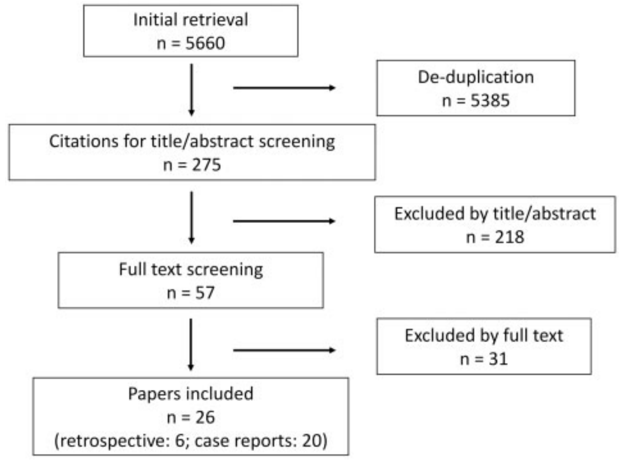

Figure 1: Flow diagram illustrating identification, selection and exclusion criteria for the articles used in this review.

There were 6 retrospective reports and 20 case reports [5–30]. A total of 67 patients were described, with an average age of 65 ± 17 years (range 17–88 years). In the group, 44 patients were men and 22 patients were women. One case report did not provide the patient's gender. Three case reports did not provide data on follow-up results (4 patients). The mean duration of follow-up results for the remaining 63 patients was 13.4 ± 16.5 months (Table 1).

Indication for endovascular ascending aorta treatment

Patients with aneurysm, pseudoaneurysm, penetrating aortic ulcer and intramural haematoma localized to the ascending aorta were included in this analysis. Also 2 ascending aorta thrombosis, 1 iatrogenic coarctation and 1 ascending aorta rupture were included. In this analysis, the majority of patients had pseudoaneurysms (65.7%). The second largest patient group included patients carrying chronic aneurysms (16.4%). The other disease rarely occurred (Table 2). In all cases, the aortic disease affected the segment of aorta comprised between the sinotubular junction and the innominate artery (IA) orifice, with no involvement of the aortic valve and the aortic root. All procedures were performed with endovascular stent grafting, and in few cases, patients underwent additional procedures. To what may concern the patients' risk scores, only 1 case series reported EuroSCORE data: mean of 13.5 ± 5.1 (range 8.5–23.8) [10]. None of the articles reported the Society of Thoracic Surgeons (STS) score, and they all report a generic 'high-risk profile' of included patients.

Access route

The most common access route for endovascular stent grafting was transfemoral (32 cases, 47.7%). Twelve patients underwent endovascular treatment through the subclavian artery (12 patients, 17.9%), and 11 procedures employed a transapical access site route (16.4%). Other access routes included the left carotid artery (5 cases, 7.5%), the right carotid artery (5 cases, 7.5%) and the iliac artery (2 cases, 2.9%) (Fig. 2).

Table 1: Case series summary of proximal endovascular aortic procedures

Author	Year	AA disease	Number of cases	Age (years)	Gender	Stent graft	Access route	Follow-up (months)	Mortality	Complications	Reintervention
Kahlberg *et al.* [5]	2016	AA thrombosis	1	64	M	Zenith	TF	6	0	No	No
Sakata *et al.* [6]	2016	AAPs	1	17	F	Gore	TF	12	0	No	No
Khoynezhad *et al.* [7]	2016	AAPs/PAUs	3/1	77, 84, 67/52	M3/F1	Medtronic	TF 4	17.5 (mean)	0	1 Ia leak 1 stroke	No
Howell *et al.* [8]	2016	AAPs	1	78	F	Medtronic	TA	6	0	1 Ia leak	No
Wada *et al.* [9]	2016	AAPs	1	42	M	Gore	LCCA	6	0	1 Ib leak	No
Piffaretti *et al.* [10]	2016	AAPs/PAUs	5/3	57, 71, 73.65, 75/73, 81, 70	M6/F2	Gore Zenith Relay	TF 5 LSA 2 RSA 1	40 (mean)	0	1 III leak	No
Ahmad *et al.* [11]	2015	Aneurysm	1	26	F	Zenith	TA	12	0	No	No
Vallabhajosyula *et al.* [12]	2015	AAPs/AAD	3	78, 54, 16	M3	Zenith	TA 2 LCCA 1	33 (mean; range 3–57)	0	No	No
Shults *et al.* [13]	2015	AAPs	1	62	M	Medtronic	TA	7	0	No	1 surgical redo
Roselli *et al.* [14]	2015	AAPs	9	38, 84, 63, 55, 73, 63, 64, 88, 61	M7/F2	Gore Cook Medtronic	TF 4 TA 1 TAX 4	12 (mean)	0	1 leak	2 surgical redo 1 endovascular redo
Allen *et al.* [15]	2015	PAUs	1	88	F	Valiant TEVAR + TAVR	TA	2	0	No	No
Preventza *et al.* [16]	2014	AAPs	7	22, 59, 84, 69, 79, 82, 64	M5/F2	Gore Medtronic	TF 5 TAX 1 Iliac 1	14.4 (mean)	1 (in-hospital)	1 conversion to open surgery	No
Shaikhrezai *et al.* [17]	2013	Aneurysm	2	59, 77	M2	Cook	TF 2	66 (mean)	0	No	No
Krankenberg *et al.* [18]	2013	Aneurysm	1	67	M	Medtronic	TA	6	Death at 6 months	Stroke and splenic infarction	No
Gray *et al.* [19]	2012	AAPs	2	65, 69	M2	Gore	RCCA 2	1	0	No	No
Joyce *et al.* [20]	2012	AAPs	3	52, 43, 68	M1/F2	Gore Zenith	RCCA 1 TF 2	6 4 36	0	1 III leak	No
Gelpi *et al.* [21]	2012	AAPs (mycotic)	1	45	M	Gore	TAX L	9	0	No	No
Vaughan-Huxley *et al.* [22]	2011	AAPs (mycotic)	1	83	F	Gore	TAX R	1	0	No	No
Saadi *et al.* [23]	2011	AAPs	2	56, 74	F/M	Gore TEVAR + PCI	TAX TF	Not reported	0	1 Ia leak	No
Kolvenbach *et al.* [24]	2011	Ascending aorta disease	11	74, 71 (mean age of 2 groups)	M5/F6	Cook Medtronic	Iliac 1 RCCA 2 LCCA 2 TA 2 TF 4	12.5 (mean; range 2–20)	1 (in-hospital)	1 Ia leak 1 Ib leak 1 Stroke	1 surgical debranching
Zago *et al.* [25]	2011	AAPs	1	74	M	Gore TEVAR + PCI	TF	5	0	No	No
Uchida *et al.* [26]	2010	Ascending aorta rupture	1	62	F	Cook	TF	7	0	No	No

Continued

REVIEW

Table 1: Continued

Author	Year	AA disease	Number of cases	Age (years)	Gender	Stent graft	Access route	Follow-up (months)	Mortality	Complications	Reintervention
Martin Pedrosa *et al.* [27]	2010	AAPs	1	59	NA	Valiant	LSA	Not reported	0	No	No
Szeto *et al.* [28]	2010	AAPs	1	78	M	Zenith TX2	TA	6	0	No	No
Yuri *et al.* [29]	2010	AAPs	1	87	M	Custom-made fenestration	TF	Not reported	0	No	No
Lin *et al.* [30]	2007	AAPs	1	78	M	Zenith	LCCA	1	0	No	No
Total			67	65 ± 17	M = 44; F = 22			13 ± 16	2 (2.9%)		

Values are expressed as numbers and % or mean ± SD.

AA: ascending aorta; AAPs: ascending aorta pseudoaneurysms; F: female; LCCA: left common carotid artery; LSA: left subclavian artery; M: male; NA: not available; PAUs: penetrating aortic ulcers; RCCA: right common carotid artery; RSA: right subclavian artery; SD: standard deviation; TA: transapical; TF: transfemoral; TAX: transaxillary; TAVR: transapical aortic valve replacement; TEVAR: thoracic endovascular aortic repair.

Combined procedures

Two articles provided interesting data about 3 patients treated with ascending aorta endograft implantation combined with percutaneous coronary treatments [23, 25]. Moreover, Allen *et al.* [15] reported 1 patient with severe aortic valve stenosis and concomitant acute ascending aorta penetrating ulcer with tamponade. The case was successfully managed using a transapical aortic valve replacement combined with an endovascular aorta repair. Some patients also required IA stenting or additional left common carotid artery stenting. However, the number of stents used could not be assessed, because some authors did not report these data.

Device selection and technical details

Details about endoaortic device type, size, location in the aorta and related complications are shown in Table 3. One case report and 2 retrospective studies did not provide details about the stent graft type, numbers, sizes, proximal and distal position. A total of 74 stent grafts were used, including 18 custom-designed, 53 off-the-shelf and 3 modified-design stent grafts. The majority of the stent grafts were placed between the origin of the coronary artery or the proximal vein graft anastomosis (redo coronary patients) and the IA. The origin of the IA was covered in 3 cases, and the left carotid artery was covered in 1 case. In 3 cases, the distal portion of the endograft was placed distally from the origin of the left subclavian artery. In these 7 cases, the IA stenting, the left carotid stenting or a surgical carotid–carotid bypass were also performed.

The average length of the stent grafts was 66.9 ± 25.9 mm (range 28.5–150 mm). The average distance between the coronary ostia and the origin of the IA was 80.4 ± 16.7 mm (range 33–105 mm) in 27 reported cases. The diameter of the ascending aorta was 39.8 ± 17.2 mm (range 22–94 mm) as reported in 39 cases. Only 12 cases recorded the diameter of the sinotubular junction and distal ascending aorta diameter. Unfortunately, anatomical parameters of the aortic root were missing in 55 cases. In addition, the measurement method in each case study was different (Table 3).

Clinical outcomes

Complications related to the endovascular ascending aorta repairs included endoleak (9 cases), stroke (3 cases), non-ST-elevation myocardial infarction (1 case) and splenic infarction (1 case) (Fig. 3). Endoleaks were the most common complication (13.4%): 7 cases were managed conservatively, whereas 2 cases required reinterventions. Three postoperative strokes (4.8%), 1 non-ST-elevation myocardial infarction (1.5%) and 1 splenic infarction (1.5%) were monitored closely. Six patients (8.9%) required reintervention after endovascular repair: 5 patients required open surgery (1 patient was operated for debranching because of Type Ib endoleak and 2 patients required surgery because of misplacement of the cuff of the stent graft in the proximal aortic arch) and 1 patient underwent endovascular reintervention for an endoleak.

The overall hospital mortality was 2.9% (2 patients died). One patient with a pseudoaneurysm died on postoperative Day 14 of respiratory failure and ventricular fibrillation. Another patient with ascending aorta aneurysm had an acute perforation of the

Table 2: Outcomes of published cases of endovascular treatment for ascending aorta disease

AA disease	Cases	Percentage	Complications	Hospital mortality
AA aneurysm	11	16.4	1 endoleak 2 strokes 1 splenic infarction	1 (9.1)
AAPs	44	65.7	6 endoleak 1 stroke 1 NSTEMI	1 (2.3)
PAUs	6	8.9	2 endoleak	0
AA thrombosis	2	2.9	None	0
AA rupture	1	1.5	None	0
Iatrogenic coarctation	1	1.5	None	0
AA IMH	2	2.9	None	0
Total	67		14 (20.9)	2 (2.9)

Values are expressed as *n* (%) or mean ± SD.
AA: ascending aorta; AAPs: ascending aorta pseudoaneurysms; IMH: intramural haematoma; NSTEMI: non-ST-elevation myocardial infarction; PAUs: penetrating aortic ulcers; SD: standard deviation.

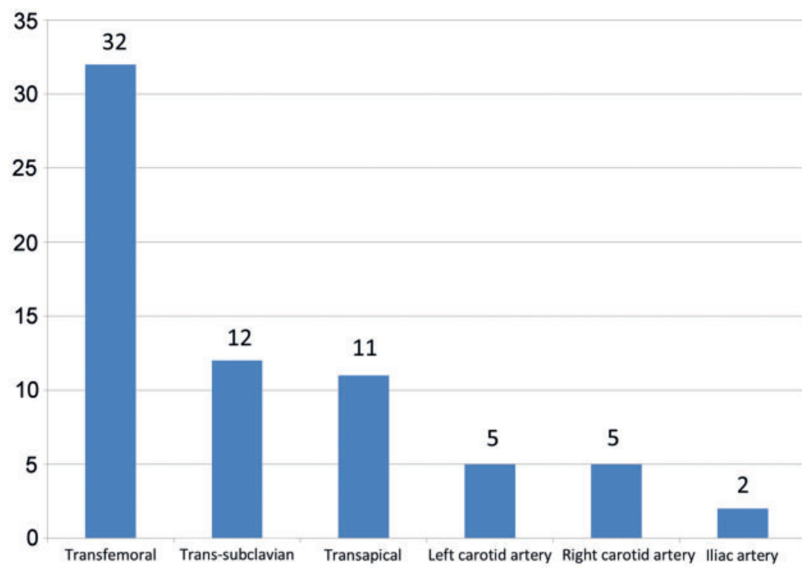

Figure 2: Access routes for endovascular ascending aorta repair.

left ventricle due to the stiff guidewire during the procedure. Emergency sternotomy was performed, and the rupture site was secured. However, the patient died of multiple organ failure 24 h later. During the follow-up period, the patient with stroke and splenic infarction complications died of sudden death after 6 months. Unfortunately, an autopsy was not performed.

DISCUSSION

Non-dissected ascending aorta disease should be managed proactively because of the risk for acute life-threatening complications and risk for rupture despite optimal medical therapy [10, 16]. However, open repair of the ascending aorta carries a higher risk when performed in elderly high-risk patients, and, therefore, endovascular treatments could be a valid option in these selected cases [1]. Since the first reported case of endovascular repair of the ascending aorta by Dorros *et al.* [2] in 2000, endovascular treatment has become a potential alternative to open-heart surgery in selected high-risk or inoperable patients.

Outcomes

Piffaretti *et al.* [10] recently reported a large case series of 8 patients with pseudoaneurysms and penetrating ulcers who underwent total endovascular repair of the ascending aorta. In this report, no endovascular-related hospital mortality, conversion to surgery, cerebrovascular accidents, valve damage or myocardial infarction occurred. A low-flow Type III endoleak was detected in 1 patient who remained asymptomatic and was managed conservatively. All patients were discharged home after a mean length of stay of 6 days. No endograft malfunction, rupture or migration was observed, and 87.5% of aortic lesions had a significant reduction in diameter (≥5 mm) at 1-year follow-up. Other reports were analysed in this review, and the preliminary results seem to be promising with low rate of major

Table 3: Technical details of the devices used for proximal endovascular aortic procedures and data of ascending aorta anatomy

Cases	Stent graft	Number of endografts	Proximal position	Distal position	Length (mm)	Size (mm)	Coronary to IA	AA diameter (mm)	STJ diameter (mm)	Distal AA diameter (mm)
AA thrombosis	CM	1	DOCA	POIA	56			39		
AAPs	OS	1	DOCA	POIA	28.5	33 × 28.5	33			
PAU	CM	1	DOCA	POIA	60	38 × 38 × 60		37.2		
AAPs	CM	1	DOCA	POIA	80	36 × 36 × 80		54.7		
AAPs	CM	1	DOCA	POIA	60	34 × 34 × 60		37.4		
AAPs	CM	1	DOCA	POIA	60	40 × 40 × 60		94.1		
AAPs	OS	2	DOCA	POIA						
AAPs	MD	1				45 × 100				
AAPs	CM	1	DOCA	POIA	65	30 × 65	70	26		
AAPs	OS	3	DOCA	POIA	45	36 × 45	80	30		
PAU	OS	1	DOCA	POIA	50	45 × 50	75	35		
PAU	OS	1	DOCA	POIA	60	45 × 60	83	41		
AAPs	OS	2	DOCA	POIA	60	45 × 60	90	37		
AAPs	OS	1	DOCA	POIA	70	45 × 70	80	39		
AAPs	CM	1	DOCA	POIA	70	38–48 × 70	70	22		
PAU	OS	4	DOCA	POIA	45	36 × 45	48	29		
AAA	CM	2	DOCA	POIA	67	36 × 67				
						38 × 67				
AAPs	CM	2	DOCA	POIA	77	38 × 77				
AAPs	CM	2	DOCA	POIA	77	38 × 77				
AAPs	OS	1	DOCA	COIA	55	22 × 55				
AAPs	MD	2	DOCA	POIA	70	40 × 40 × 70				
	OS				52	46 × 46 × 52				
AAPs (9 cases)							90.3 ± 10	62 ± 8	36 ± 3	50 ± 10
PAU + AS	MD	2	DOCA	POIA	80	46 × 80				
	OS				100	45 × 100				
AAPs	OS	2	DOCA	COIA	33	28 × 33				
AAPs	OS	1	DOCA	POIA	100	34 × 100				
AAPs	OS	2	DOCA	POIA	75	36 × 75				
					100	37 × 100				
AAPs	OS	1	DOCA	POIA	100	28 × 100				
AAPs	OS	2	DOCA	COIA and 2COLCCA	100	40 × 100				
AAPs	OS	1	DOCA	POIA	100	40 × 100				
AAPs	OS	2	DOCA	POIA	45	32 × 45				
AAA	CM	2	DOVG	POIA	42	34 × 42				
AAA	CM	1	DOVG	POIA	44	38 × 44				
AAA	OS	2	DOCA	DOLSA	150	46 × 46 × 150				
						46 × 46 × 100				
AAPs	OS	1	DOCA	POIA	45	34 × 45	78			
AAPs	OS	2	DOCA	POIA	45	32 × 45	85	25	28	36
AAPs	OS	1	DOCA	POIA	33	28.5 × 33				
AAPs	OS	3	DOCA	POIA	54	28 × 54				
					33	28 × 33				
AAPs	OS	1	DOCA	POIA	64	34 × 64				
AAPs	OS	2	DOCA	POIA	33	26 × 33	48	24.6		
						28.5 × 33				
AAPs	OS	2	DOCA	POIA		26 × NA				
AAPs	OS	2	DOCA	POIA	45	31.5 × 45	85	29		
AAPs	OS	1	DOCA	POIA	100	40 × 100	105	38		
AA disease (11 cases)			DOCA		100.9			68.1		
AAPs	OS	1	DOCA	POIA	100	40 × 100	105	38		
AA rupture	CM	1	DOCA	DOLSA						
AAPs	OS	1	DOCA	COLCCA	100	32 × 100				
AAPs	OS	2	DOCA	POIA	77	38 × 77	77		31	34
AAPs	CM	1	DOCA	DOLSA			85		41	41
AAPs	OS	3	DOCA	POIA	36	32 × 36	60	30		
Total	CM = 18	74			67 ± 26		80 ± 17	40 ± 17		
	OS = 53									
	MD = 3									

Values are expressed as *n* (%) % or mean ± SD. Empty entries represent not available record.

AA: ascending aorta; AAA: ascending aorta aneurysm; AAPs: ascending aortic pseudoaneurysms; AS: Aortic Stenosis; CM: custom-made; COIA: covering the origin of the IA; COLCCA: covering the origin of the LCCA; DOCA: distal to the origin of the coronary artery; DOVG: distal to the origin of the vein graft; DOLSA: distally to the origin of the LSA or the proximal descending aorta; IA: innominate artery; IMH: intramural haematoma; LSA: left subclavian artery; LCCA: left common carotid artery; MD: modified design in the operating room; NA: not available; OS: off-the-shelf; PAU: penetrating aortic ulcers; POIA: proximal to the origin of the innominate artery; SD: standard deviation; STJ: sinotubular junction.

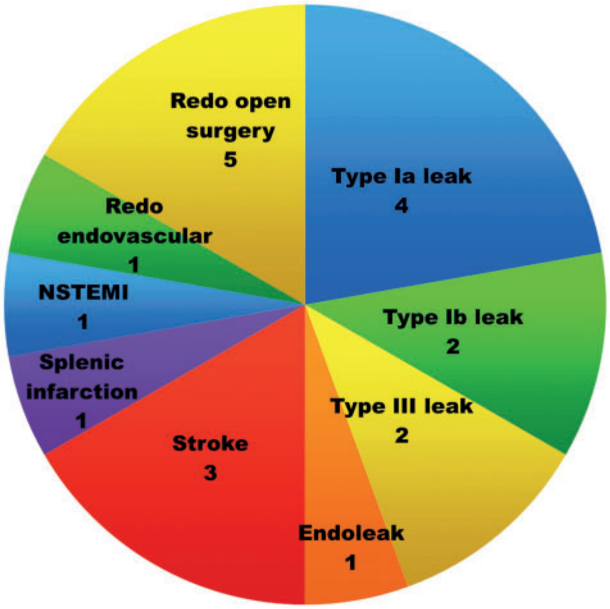

Figure 3: List of complications occurred after endovascular ascending aorta repair. NSTEMI: non-ST-elevation myocardial infarction.

complications and mortality (2.9% of mean in-hospital mortality). However, there could be a risk of publication bias, because we based our analysis on published small case series and case reports, and, therefore, unsuccessful cases might have not been reported by other authors.

All publications concluded that the endovascular repair of the ascending aorta is a feasible, safe and effective method for treating ascending aorta aneurysm, pseudoaneurysms and penetrating aortic ulcers in high-risk or inoperable patients. Nevertheless, a word of caution is required. In a selected subset of patients with lesions, acceptable mid-term results were obtained with both standard and custom-designed endografts. It is worth mentioning that significant variability exists, both anatomically and physiologically, in patient selection. Careful sample selection is required before drawing any conclusions from the presented data [4].

Access route

As to the access route, the retrograde transfemoral and trans-subclavian approaches were the most commonly used access sites, in particular when standard thoracic endoprosthesis and delivery systems were used. However, many authors agree that the transapical access offers more advantages when operating on the ascending aorta, although it is more invasive and requires cardiac surgery skills to be performed (we aim to underline the importance of a Heart Team on-site) [12, 13, 15]. Transapical access provides a short working distance to the ascending aorta and addresses the inadequate length of current delivery systems, giving the operator a significantly higher degree of device control during the device deployment and, therefore, enabling a more precise landing.

Endoleak

Another issue of endovascular procedures is the endoleak. In the reported cases, the endoleak rate was 13.4% including Type Ia, Type Ib and Type III endoleak. Luckily, the majority were small endoleaks managed conservatively. Six (8.9%) patients required reintervention by means of an endovascular procedure or open surgery. Again, we should remember that these data come from a small group of patients with short follow-up, and some endoleak can also appear years later.

The devices

Because of the complex anatomy, physiology and pathology of the ascending aorta, the endovascular treatment of the ascending aorta is more challenging than TEVAR of the aortic arch, descending aorta or abdomen aorta. In particular, the difference between the outer and the inner curve of the ascending aorta, the 3D motion of the ascending aorta, the distance between the sinotubular junction and the IA, the coronary ostia level and also the presence of a concomitant aortic valve disease can make the design of the ascending aorta endovascular device a challenge. Moreover, the endovascular device requires a healthy segment of proximal aorta for sealing and fixation but in patients with ascending aorta disease there is merely enough healthy aorta. Thus, patient selection is crucial for aligning aortic anatomy with specific device designs.

So far, only isolated aortic diseases located between the sinotubular junction and the origin of the IA (with no involvement of the aortic valve and the aortic root) may be treated with the available endovascular graft technology. As a matter of fact, in these 67 reported cases, the endovascular device was mainly located between the coronary ostia and the IA, and in 7 patients, the origin of the IA, left common carotid artery or left subclavian artery was covered by the graft. Therefore, another major issue is the absence, for the time being, of specifically designed stent graft devices and dedicated delivery systems for the ascending aorta. Currently available stent grafts for endovascular treatment of ascending aorta disease are thoracic endografts that do not fulfil the requirements for placement in the ascending aorta anatomy. They are, unfortunately, too long to be deployed between the coronary arteries and the IA, and therefore, many surgeons shortened the thoracic endografts on the operating table before deployment into the ascending aorta [9, 13, 15].

Future perspectives

The design and manufacturing challenges to this problem are much more complicated than simply making shorter grafts or longer cuffs or altering the nose cones of the currently available devices. The anatomical and physiological complexity of the ascending aorta is different from that of the descending thoracic or abdominal aorta. To extend the proximal landing zone to the aortic root and aortic valve annulus, device modifications are much needed to address the problem of the valve performance and coronary perfusion.

CONCLUSION

Despite its advantages, the endovascular treatment can be applied to the ascending aorta to a limited extent because of the anatomical and physiological challenges. The available literature on endovascular treatment of ascending aortic disease still consists of single case reports or small case series with a few studies describing the short- and mid-term outcomes. The follow-up length is, for the time being, too short to draw conclusions concerning the reliability of the endovascular technique for ascending aorta diseases. Therefore, general conclusion from solid statistical analysis with adequate samples is lacking. Although the safety and effectiveness of endovascular graft technology in ascending aorta disease need further studies, the feasibility and the advantages of this technique are becoming widely accepted in selected cases. Indeed, clinical trials with large samples are needed. Several technical problems including the development of specific device designs that preclude the wide application of this procedure must be solved. As the understanding of user and market needs of endovascular treatment device will increase, the technical problems will be resolved step by step. Also catheter-based treatments will become the mainstream option for future cardiac operations including ascending aortic lesions.

Conflict of interest: none declared.

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